AD-778 824

AN EMERGENCY LIFE-SAVING INSTANT EXIT SYSTEM FOR CARGO, CARGO-TRANSPORT AND PASSENGER AIRCRAFT. VOLUME II

M. C. Anderson, et al

Explosive Technology, Incorporated

Prepared for:

Aeronautical Systems Division

February 1974

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

ACCESSION for		
NTIS	White Section	☑
DDC	Buff Section	☐
UNANNOUNCED		☐
JUSTIFICATION		
BY		
DISTRIBUTION/AVAILABILITY CODES		
Dist.	AVAIL. and/or SPECIAL	
A		

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

jf

UNCLASSIFIED

Security Classification

AD-778824

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Explosive Technology P. O. Box KK Fairfield, California 94533	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE

AN EMERGENCY LIFE-SAVING INSTANT EXIT SYSTEM FOR CARGO, CARGO-TRANSPORT AND PASSENGER AIRCRAFT

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Report, Volume II, June 1971 to May 1973

5. AUTHOR(S) (First name, middle initial, last name)

Anderson, M. C.
Burkdoll, Frank B.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
February 1974	31	0

8a. CONTRACT OR GRANT NO. F33657-70-C-1138 b. PROJECT NO. N/A c. N/A d. N/A	9a. ORIGINATOR'S REPORT NUMBER(S) ASD-TR-71-41 Volume II 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) Volume I

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES None	12. SPONSORING MILITARY ACTIVITY Life Support System Program Office (SML-5) Aeronautical Systems Division Air Force Systems Command ~~Wright-Patterson Air Force Base, Ohio~~ 45433

13. ABSTRACT

The results of flight-test phase of Contract F33657-70-C-1138 for an Emergency Life-Saving Instant Exit (ELSIE) System for military and commercial cargo, cargo-transport and passenger aircraft are described. The ELSIE System opens emergency exits in aircraft almost instantaneously and can be designed to open all exits at one time or on a selective basis. The Flight-Test Directorate of the Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, performed the described testing. The design evolved from Explosive Technology's STEN (Stored Energy) Passenger Egress System originally developed in 1967 and continuously demonstrated since then. This document is Volume II of a two-volume report. Volume I describes the design and ground-test phases of the program.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. ELSIE System						
2. Emergency Exits for Aircraft						
3. Outward Opening Exit						
4. Rapid Opening Exit						
5. Seal Vulcanization						
6. Structural Deformation						
7. Inadvertent Operation						
8. Ground Testing of Emergency Exit						
9. Flight Testing of Emergency Exit						
10. Upper Limits of Human Endurance						
11. Survivable Aircraft Accidents						
12. Emergency Egress Operation						

UNCLASSIFIED
Security Classification

ia

*U.S.Government Printing Office: 1974 — 758-434/553

ASD-TR-71-41
Volume II

AN EMERGENCY LIFE-SAVING INSTANT EXIT SYSTEM FOR CARGO, CARGO-TRANSPORT AND PASSENGER AIRCRAFT

M. C. ANDERSON
F. B. BURKDOLL

Approved for public release; distribution unlimited.

ic

ASD-TR-71-41
Volume II

FOREWORD

Passenger and cargo aircraft construction and propulsion have made tremendous technological advances in the past two decades. These advances have yielded aircraft capable of carrying over 300 passengers per flight. As the number of passengers increased, the need for more exits and adequate egress procedures became apparent if passenger safety was to be maintained. The availability of positive, rapid-opening emergency exits is a primary consideration in the broad field of aircraft safety. The shaped charge concept for emergency exits as covered by this report applies the latest state of the art to this aspect of passenger emergency egress.

It is recognized that the design of rapid opening exits is not the only factor in the expedient egress of passengers from a survivable aircraft accident. The attitude of the aircraft, presence of fire, physical condition of passengers, efficiency of the aircrew, interior layout, and structural damage inflicted on the aircraft at impact -- these are additional factors involved in an egress operation. Nevertheless, a rapid-opening exit is considered to be a primary requirement for an efficient emergency ground egress system.

Under Contract F33657-70-C-1138 from the Life Support System Program Office/Aeronautical Systems Division/Air Force Systems Command/Wright-Patterson Air Force Base, Explosive Technology (ET) has completed the design, ground testing and flight testing of the Emergency Life-Saving Instant Exit (ELSIE) System. This system was a further refinement of ET's STEN (Stored Energy) Passenger Egress System originally developed with company funds in 1967.

The Air Force Program Manager was Mr. James J. Reilley, ASD/SMLN. The Project Engineer for the ground-test phase was Captain Burton P. Chesterfield. That effort commenced in June 1970 and continued through

May 1971, as reported in Volume I of this two-volume report. This report represents Volume II and covers the flight testing of the ELSIE System, which commenced in June 1971 and was completed in May 1973. The Air Force test director for the flight-test phase was Mr. Robert W. Markland.

This technical report has been reviewed and is approved for publication.

G. P. SANTI
Chief, Crew Support Division
Directorate of Crew and AGE
Subsystems Engineering

WILLIAM M. QUINN, Colonel, USAF
System Program Director
Life Support System Program Office
Deputy for Subsystems

ASD-TR-71-41
Volume II

ABSTRACT

The results of the flight-test phase of Contract F33657-70-C-1138 for an Emergency Life-Saving Instant Exit (ELSIE) System for military and commercial cargo, cargo/transport, and passenger aircraft are described. The ELSIE System opens emergency exits in aircraft almost instantaneously and can be designed to open all exits at one time or on a selective basis. The 4950th Test Wing of the Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, performed the described testing. The design evolved from Explosive Technology's (ET) STEN (Stored Energy) Passenger Egress System originally developed in 1967 and continuously demonstrated since then. Design and ground testing were performed by ET; the results of that effort are described in Volume I of this report (June 1971). This document is Volume II of the two-volume report.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION I

INTRODUCTION

The ELSIE System will open emergency exits almost instantaneously in an aircraft fuselage after a crash-landing, providing the passengers and flight crew with immediate avenues of escape. (See Figure 1.) The unique characteristics of the ELSIE System are:

a. It opens emergency exits in less than 0.001-second.
b. It can be used to automatically deploy slides, life rafts or slide/raft combinations.
c. It is immune to jamming by structural deformation, ice or seal vulcanization.
d. The exit door always jettisons outward; successful function cannot be prevented by onboard obstructions or congestion.
e. It is instantly operable from the interior or exterior following a crash, yet cannot be operated inadvertently.
f. It requires no special structure to carry normal fuselage stresses around the potential emergency exit.

The design study of the Emergency Life-Saving Instant Exit System (see Volume I) resulted in a system composed of five basic components: a safe/arm mechanism, shielded mild detonating cord lines, a flexible linear shaped cutting charge, an interior initiation handle, and an exterior initiation handle. The safe/arm mechanism is an electro-mechanical device that:

a. Requires only momentary application of electrical power to arm from the SAFE position or to safe from the ARM position.
b. Will not change from SAFE to ARM position or vice versa once in that position without momentary application of electrical power.
c. Rotates the explosives out-of-line in the SAFE position.

Shielded mild detonating cord lines are fully qualified energy transfer lines that are currently being used on the F-111, F-14, F-15, and S-3A aircraft, and many other programs. The cutting charge, with a similar history of use, is a chevron-shaped flexible linear shaped charge

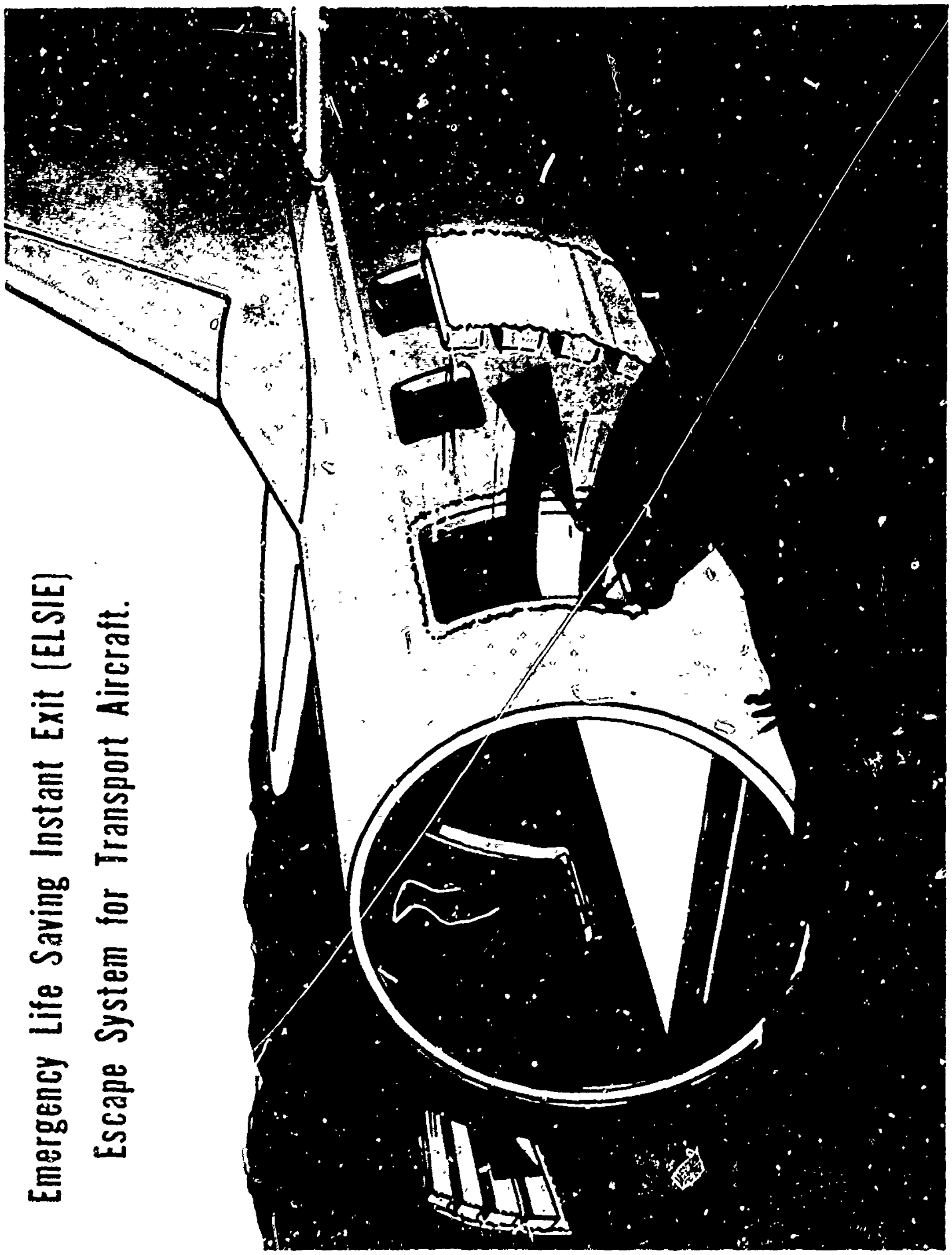

Figure 1. Emergency Life-Saving Instant Exit (ELSIE) System

sheathed in metal that severs the skin and/or ribs of the aircraft on which it is mounted. The initiation handles are standard handles that must be operated manually once the system is armed.

Operation of the ELSIE System requires that the safe/arm mechanism be electrically armed, preferably from the flight deck, then manually functioned by pulling either the interior or exterior handle. Operation of the initiation handles is accomplished at the ELSIE System station. Thus, the ELSIE System requires two separate functions in the proper sequence at different locations to be made operational.

The original design of the basic ELSIE components was made and demonstrated by ET in its STEN (Stored Energy) Passenger Egress System, developed with company funds in 1967. Under Contract F33657-70-C-1138 from the Life Support System Program Office, Wright-Patterson Air Force Base, ET further refined the STEN System design to meet specified goals of the U.S. Air Force. The system was also renamed "Emergency Life-Saving Instant Exit" to indicate the purpose of the system.

The Air Force contract specified design criteria and a two-phase test program: ground tests and flight tests. The ground tests, conducted by ET and reported in Volume I, represented both normal operational environments and dynamic/thermal environments associated with aircraft crashes. Test units for this phase were subscale panels representing the installation planned for the flight-test phase.

Flight tests, the subject of this volume, were conducted by the 4950th Test Wing at Wright-Patterson Air Force Base. Test units were four normal C-131B over-the-wing bailout doors modified to accommodate the ELSIE System. Once the ELSIE-modified bailout doors were installed in the test-bed aircraft, the aircraft flew normal missions to accumulate at least 250 hours of flight time.

The ELSIE Systems were armed during takeoffs and landings and disarmed during normal flight using normal aircraft electrical systems. After accumulating the required number of flight hours, the ELSIE-equipped doors were removed from the aircraft and successfully functioned in a test stand at Wright-Patterson Air Force Base. These functional tests demonstrated the capability of the ELSIE System to withstand aircraft operational environments for an extended period of time without deterioration.

SECTION II
SUMMARY OF GROUND TESTS

The entire ELSIE System was built into 24- x 24- x 3-inch ground-test panels for purposes of conducting the ground-test phase of the program. These tests are described in detail in Volume I. Only an external power supply was required to provide the electrical energy needed to arm the safe/arm mechanism. These ground-test panels were then subjected to the following tests:

a. Vibration
b. Operating Temperature
c. 40-ft Drop
d. 40g Shock
e. Structural Deformation
f. Water Immersion
g. Cook-Off
h. Fuel Ignition
i. Inadvertent Detonation by Fire

The tests to which the ground-test panels equipped with ELSIE Systems were subjected can be categorized into normal operational environments and dynamic and thermal environments associated with aircraft crashes. The thermal tests were basically safety tests that demonstrated the compatibility of the ELSIE System with fire or potential fire present at all aircraft crashes.

Normal operating environment tests comprised vibration, functional tests at operating temperatures of +200°F and -65°F, and 40-foot packaged drop tests. Normal vibration levels were exceeded because of a fatigued bracket on the ground-test panel without affecting the performance of the ELSIE System. Functional tests at +200°F and -65°F demonstrated the

ability of the ELSIE System to perform at these thermal extremes. The final operational test, the 40-foot packaged drop, was conducted with the ground-test panel out of its shipping container. Though not a test requirement, this system was functioned satisfactorily after the drop test.

Shock and structural deformation tests demonstrated the ability of the ELSIE System to endure the maximum dynamic loads associated with a survivable aircraft accident. Shock loads of 20 and 40g for 0.10-second duration along three orthogonal axes did not degrade the system's performance; even bending the test panels to an included angle of 150° did not reduce the performance capabilities of the system. Thus, it was concluded the ELSIE System is immune to dynamic loads at least equal to the upper limits of human endurance.

Thermal environments were simulated by three tests: cook-off, inadvertent detonation by fire and fuel ignition. The cook-off test proved that the out-of-line characteristic of the safe/arm mechanism will prevent inadvertent initiation of the ELSIE System and that sustained exposure to 425°F will not cause the system to detonate. Inadvertent detonation by fire tests simulated a fuel-fed fire on the outside of the aircraft. The test panels subjected to this test functioned properly, even though the skin on one test panel was burned completely through. (Test requirements were only that the ELSIE Systems not autoignite.) Finally, 10 fuel ignition tests were conducted by spraying JP-4 and 115/145 grade aviation gasoline on the panels and functioning the panels to determine if the release of the explosive energy would start a fire. All tests were negative, i.e., no fires resulted.

A final test requirement was that the ELSIE System function when immersed in salt water. The ELSIE System completely cut the skin of the test panel, as required.

During the test phase, a Fastax camera was used to record the significant events at framing rates above 1500 frames/second. These films revealed: (1) the maximum ejection velocity of the jettisonable section of the ground-test panel was 6 to 8 ft/sec (approximately 5 mph); and (2) the time to remotely pull the intiation handle and create the escape path was 0.027-second. These data show that the ELSIE System operates faster than any exit in use today and that it does not present a hazard to personnel who may be inside or outside the aircraft and near the exit when the ELSIE System is functioned.

The ELSIE System was designed to meet a goal of 0.999 reliability at 0.90 confidence. All electrical and mechanical parts were selected to meet this goal, and special tests were devised and executed to demonstrate that all explosive components successfully fulfilled the design objectives. Explosive initiation, transfer, and metal severance were satisfactorily demonstrated. The most conservative statistical estimation has shown that all performance data were compatible with, or superior to, that obtained from prior experience on comparable hardware. No significant changes were required or made in the original estimates. The predicated reliability and confidence were thoroughly demonstrated.

The ELSIE System was designed for a total life of seven years, including an installed life of not less than five years. This is current aircraft experience. As this type of system ages in practice, extension of useful life is anticipated. Maintenance is essentially zero. In the event of failure, the "press-to-test" lamp may need to be replaced; otherwise the entire panel is removed and another substituted. No explosive ordnance knowledge or capability is required in routine operation, installation, or replacement.

The ELSIE System design was based on proven systems used for many years in aerospace and ground applications. The ground tests demonstrated that ELSIE could only be rendered inoperable by distortion far in excess of that encountered in any possible survivable crash; however, ELSIE could not be inadvertently actuated by any cause.

SECTION III
FLIGHT-TEST PREPARATION

Following the successful conclusion of the ground-test phase of the program (see Volume I), ELSIE System components were built up for installation in the normal over-the-wing bailout doors of C-131B aircraft that would be used as test-beds for the flight-test phase of the program.

In June of 1970, an order was placed with Canadair Ltd., Montreal, Quebec, Canada, for the required replacement door for the C-131B aircraft. Door panels were received at Explosive Technology's plant in Fairfield, California on 30 March 1971. The doors were modified to the extent necessary to install the ELSIE System without decreasing the structural integrity of the door panel. The skin was not penetrated for mounting the system.

In order to provide access for functioning the system from outside the aircraft, the exterior handle box and closure were installed through the external skin of the door panel. The general arrangement of the components of the system is shown in Figure 2. The external handle closure is shown in the view of the outside of the door (Figure 3). The internal trim of the door panel was modified as shown in Figure 4. Electrical power was provided by a battery pack.

The safe/arm installations were checked out at ET after component installation was completed. Two doors were then shipped to the 4950th Test Wing at Wright-Patterson Air Force Base on 22 July 1971. The second two were shipped 27 August 1971.

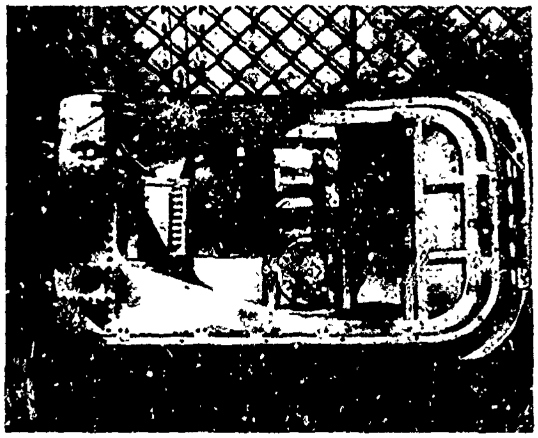

Figure 2. ELSIE Flight Test Door Component Arrangement

Figure 3. ELSIE Flight Test Door Installed on C-131B, Exterior

Figure 4. ELSIE Flight Test Door Installed on C-131B, Interior

SECTION IV

FLIGHT TESTING

Upon final acceptance of the door panels at the 4950th Test Wing, Wright-Patterson Air Force Base, and prior to installation into the aircraft, the doors were subjected to a series of thermal environments during which arming and safing cycles were performed. At the low temperature extremes, the batteries failed to operate the safe/arm device properly. When 28 v.dc. was applied, no problem was experienced. It was determined that the available energy level from the batteries at these reduced temperatures was insufficient to actuate the safe/arm device. The battery circuit was bypassed; aircraft power was connected directly to the safe/arm switch in the door. To accommodate this modification, an electrical connector was mounted in the inside trim of the door panel. After the door was mechanically installed in the aircraft, the aircraft power was connected to the ELSIE safe/arm device through this connector. In this manner, the entire system, except for the battery power supply, was operational as designed.

Door Nos. 3 and 4 were installed in aircraft C-131-B-820 on 23 May 1972. Door No. 3 was removed from the aircraft on 11 January 1973 after it had experienced 291.5 hours of normal flight time on 67 missions.

Door No. 4 experienced some down-time for inspection and repair of leaking seals, thereby requiring additional time to reach the desired 250 hours of normal flight. The door was finally removed from the aircraft on 6 March 1973 after accumulating 251 hours of normal flight time on 53 missions.

For each flight, the safe/arm mechanism was cycled for each takeoff and landing. These cycles were in addition to the approximately 100 cycles performed at temperature extremes in the laboratory before installing the doors on the aircraft.

Door No. 4 was set up for functional testing on 20 March 1973 in a test stand in Area C at Wright-Patterson Air Force Base (Figures 5, 6, and 7). The door (and each succeeding door) was visually inspected prior to actually functioning in the test fixture.

In order to synchronize the high-speed camera coverage of the ELSIE System in action, a spring-loaded lanyard puller with a solenoid actuated pin puller was used to pull the ELSIE inside handle. The required squeeze action was accomplished by strapping the handle in the compressed position and pinning the lanyard clevis to the strap clamp. The lanyard was fed through an alignment sheave and the opposite end was made fast to the spring-loaded plunger.

Several attempts to function Door No. 4 with the above fixturing were made without success. The lanyard was not being pulled hard enough to cock and release the firing pin. The final, successful actuation was accomplished manually. The Test Director pulled the lanyard by hand and the system functioned successfully as illustrated in Figures 8 through 11.

Severance of the skin was clean all around the periphery of the opening. One small piece of the plastic inside door trim, approximately 2-1/2 by 5 inches in area, was broken off adjacent to the safe/arm location. This piece was found about two feet inboard after the firing.

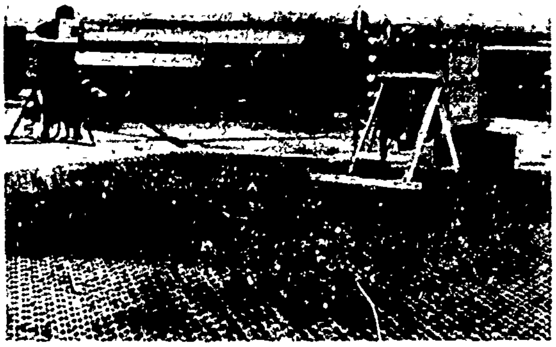

Figure 5. Test Area C at Wright Patterson Air Force Base

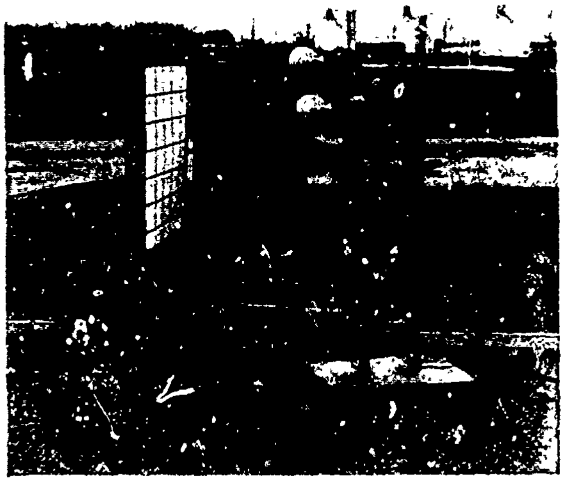

Figure 6. ELSIE Door Installed in Test Stand, Outboard

Figure 7. ELSIE Door Installed in Test Stand, Inboard

Figure 8. ELSIE Door No. 4 Before Function

Figure 9. ELSIE Door No. 4 After Function

Figure 10. ELSIE Door No. 4 After Function

Figure 11. ELSIE Door No. 4 After Function

The door was inspected after the firing for an indication of the actuation problem; none were apparent. It was assumed that the spring travel and force of the simulated "handle puller" was not adequate to overcome the friction of lanyard in the guide and the sheave. Before the next test, the handle puller was reworked to provide a longer stroke. The films of the first test were reviewed prior to conducting the test of Door No. 3. The motion pictures showed a normal system operation.

Door No. 3 was set up in the same test stand, with the reworked handle puller. Upon first command, the foor functioned satisfactorily as shown in Figures 12 through 15.

A similar piece of the plastic trim was broken from the inside trim of the door. This 2-1/2 by 5 inch piece was found within 18 inches of the door. Although the broken trim is not considered a personnel hazard, due to its low velocity, its failure can be prevented by a change in trim material to one having more flexibility or strength. The lanyard friction problem can also be alleviated by selection of a better heatshrink tubing for the handle-S/A cable. The material used on Door No. 3 (RNF tubing) should be used in preference to that used on Door No. 4 (CRN tubing).

Door Nos. 1 and 2 were installed on aircraft C-131-B-821 on 7 September 1972. On 30 March 1973, after 256.4 hours of normal flight time on 61 missions, both doors were removed. No problems were encountered during the flight operations. Again, the safe/arm mechanism of each door was cycled for takeoffs and landings, in addition to the approximately 100 cycles performed in pre-flight testing.

Figure 12. ELSIE Door No. 3 Before Function

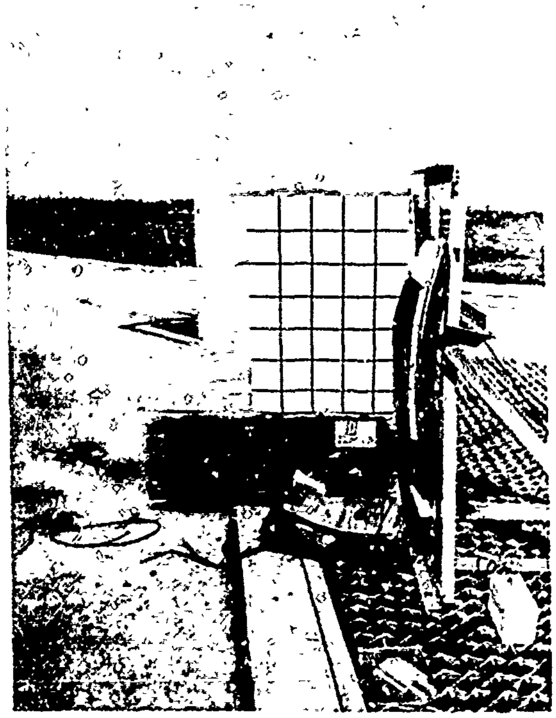

Figure 13. ELSIE Door No. 3 After Function

Figure 14. ELSIE Door No. 3 After Function

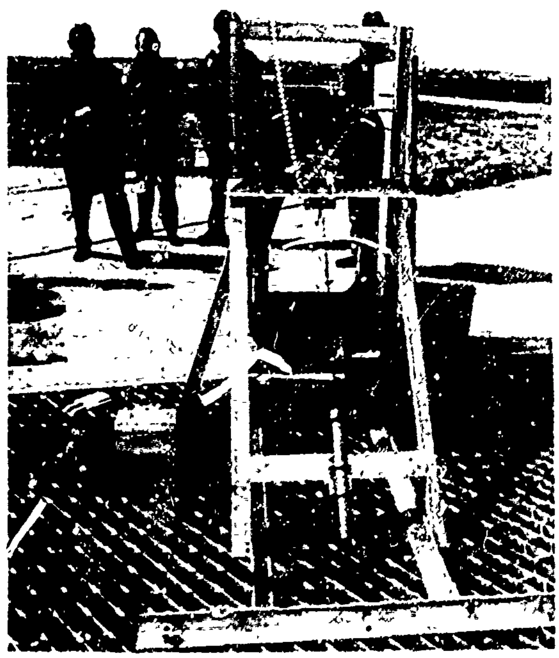

Figure 15. ELSIE Door No. 3 After Function

On 23 May 1973, Door No. 2 was set up in the test stand and functioned. The system severed the skin normally (Figures 16 and 17). The door trim was not relieved on this door to the same extent as the other three doors. This testing condition caused the connector on the jettisonable portion to hang up on the stationery door trim, preventing the cut panel from falling free.

When it was determined by visual inspection that the egress aperture was clearly and completely cut and that the electrical connector, used for access to aircraft power, was the only thing keeping the door from falling out, it was nudged open (Figure 18).

The final door, Door No. 1, was set up on 23 May 1973 and functioned normally (Figures 19 through 22).

Figure 16. ELSIE Door No. 2 Severing Skin

Figure 17. Severed Panel Held in Place by Electrical Connector

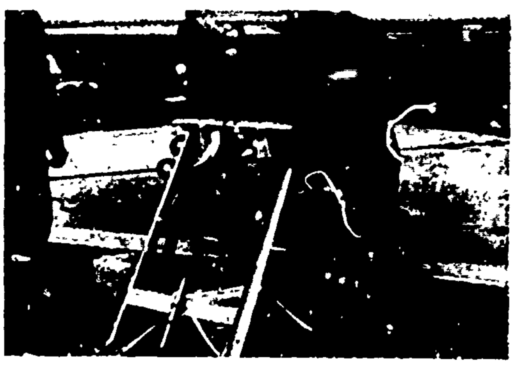

Figure 18. Clear Opening Made Through Door No. 2

Figure 19. ELSIE Door No. 1
Before Function

Figure 20. ELSIE Door No. 1
After Function

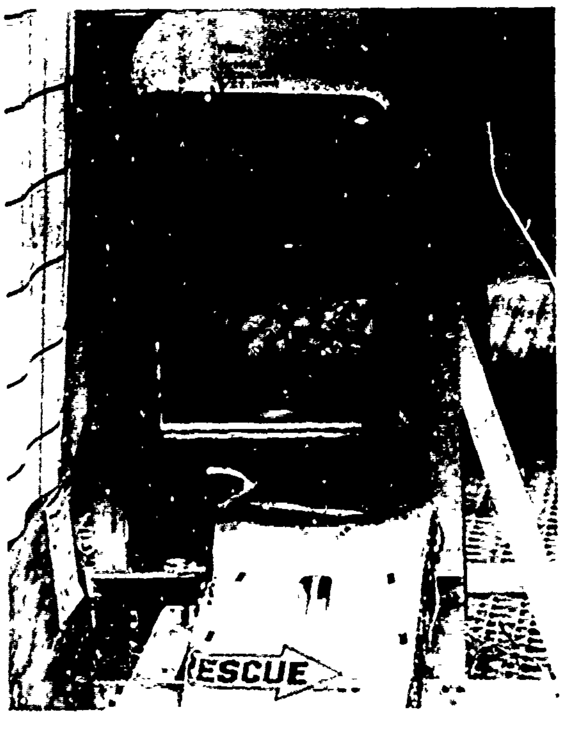

Figure 21. ELSIE Door No. 1
After Function

Figure 22. ELSIE Door No. 1
After Function

SECTION V
CONCLUSIONS AND RECOMMENDATIONS

Design and testing of the ELSIE System have shown that it is an emergency egress system that is at least two orders of magnitude faster than any system in use today on cargo or passenger aircraft, either military or civilian. This is solely attributable to the fact that the ELSIE System derives its energy from solid explosives. The intrinsic safety and reliability of the ELSIE System was demonstrated by the test program discussed in Volume I and in Section IV of this volume.

Specific design objectives were set down at the outset of the program. All these objectives were met. These features, coupled with the intrinsic characteristics of the ELSIE System, yield an emergency exit that:

a. Is always outward opening.
b. Is operable by a passenger or crewmember in less than 0.027-second when armed.
c. Is maintenance free and highly reliable.
d. Is immune to the environments of a survivable crash, i.e., fire, jamming, dynamic loads.
e. Can be integrated into the aircraft without affecting the function of the aircrew or occupying usable space.
f. Does not affect the aerodynamic characteristics of the aircraft.
g. Can be controlled by the aircraft commander, thus making it operable only when the probability of crash is greatest.
h. Requires only momentary power to arm or safe.
i. Can be operated from inside or outside the aircraft.

The ELSIE System also imparts enough energy to the jettisoned section to deploy a slide or slide/raft combination. Thus, it can be seen that the ELSIE System not only creates emergency exits rapidly, but also

offers a technological advancement for deployment of any type of survival equipment that would normally need to be deployed in an emergency, including slides, rafts, slide/raft combinations, beacon markers and survival kits.

The adaptability of the ELSIE System to existing aircraft has been evaluated and shown to be feasible and desirable. Furthermore, the ease of repair of an exit created by the ELSIE System was shown to be reasonable and prudent. The ground-test panels were rebuilt after each firing, with those parts of the panel that represent the airframe reused three or more times. These inherent adaptability and repairability characteristics of the ELSIE System illustrate its ease of retrofit into existing aircraft with minimum modification to the airframe.

One of the features of the ELSIE System as designed for this test program is its two-phase operating feature. That is, the system must be armed from the cockpit, then manually functioned at the door station. However, other designs are possible and, in fact, have been built.

A variation of the ELSIE System has been installed in AC-130E aircraft with completely manual operation. No electrical power is required in this installation. Another variation of ELSIE has been installed in Gates Learjet prototypes for FAA-required flight tests. This system also provides for purely mechanical operation. These systems were designed to be operated by experienced crew members with the training and capability to function rationally under emergency conditions.

Based on the work accomplished, it is recommended that the ELSIE System be considered for installation in other passenger aircraft to improve survivability in survivable crashes.